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Assessing the magnitude of freight traffic generated by office deliveries

Ivan Sanchez-Diaz

Technology Management and Economics, Chalmers University of Technology, Sweden

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ABSTRACT

This paper studies the impact of offices on urban freight traffic. Research on freight activity generated by offices is very limited because they are not seen as important contributors to urban freight traffic, and because the amount of deliveries per office is very small compared to the number of deliveries per establishment in freight-intensive sectors (e.g., retail, wholesale, manufacturing). However, the number of offices in cities is so large that altogether they represent a significant share of urban deliveries and generate a nonnegligible share of urban freight traffic. Hence, the relevance of quantifying their freight trip generation. This paper uses the City of Stockholm as a case study. The author collected data from offices and other establishments, estimated regression models and applied them to the city. The results show that offices represent 36% of establishments in Stockholm, 62% of employees and are responsible for 15% of freight trips generated in the city.

1. Introduction

Urban freight models are crucial to support infrastructure planning and effective freight policy. A better understanding of freight activity, freight flows and resulting freight traffic improves public authorities' transportation decision-making, informs policy makers on potential outcomes of their policies, and provides input to real estate developers and architects about the facilities required to fulfil future freight demand.

As freight is a result of economic activities, it is important to identify the relationship between sectors of the economy and their freight generation patterns. Holguín-Veras et al. (2015) classify economic activities into (i) freight intensive-sectors (e.g., manufacturing, wholesale, retail, restaurants) where production, transformation and consumption of goods are the main value-adding activity, and (ii) non-freight-intensive sectors (e.g., information, finance, entertainment, advertisement) where services are the main value-adding activity and goods are secondary. Most urban freight studies focus on freight intensive-sectors because they have frequent and large size deliveries, while non-freight-intensive sectors are often ignored and are seldom the subject of freight studies. But, although non-freight intensive sectors have fewer parcel deliveries per establishment, they also represent a large share of establishments in cities and thus are responsible for a significant amount of freight trips.

One method that has become common in the recent years is the collection of establishment-level data and estimation of freight trip generation models. These models estimate the total number of freight-related trips generated by an establishment as a function of business size, economic activity and other business' attributes (Sánchez-Díaz et al., 2016). As the unit of study are establishments, they can be easily aggregated at different geographical levels such as, at a shopping center level, at a transportation analysis zone, or at the

E-mail address: ivan.sanchez@chalmers.se.

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city level to study freight generation patterns; or serve as input for simulations and tour-based models (Gonzalez-Feliu and Routhier, 2012; Holguín-Veras and Aros-Vera, 2014; Sánchez-Díaz et al., 2015; Toilier et al., 2018).

The literature on freight trip generation has been expanding in the recent years (Iding et al., 2002; Holguín-Veras et al., 2011; Günay et al., 2016; Sanchez-Diaz, 2016; Alho and e Silva, 2017; Gonzalez-Feliu and Sánchez-Díaz, 2019; Sahu and Pani, 2019), but there is little known about the amount of freight traffic that is generated by non-freight intensive sectors (referred to offices for the remaining of this paper). In this context, this paper seeks to (i) estimate freight trip generation models for offices and (ii) assess their contribution to the overall freight trip generation in a city. The City of Stockholm was selected as a case study.

2. Literature review

Urban freight traffic can be quantified using different sources of data, such as, traffic counts, transport operators' data, and establishments' surveys. Traffic counts are simpler to conduct for small areas, and transport operators' data provide a high level of detail about shipments. However, establishments data has gained prominence in the recent years because they connect freight traffic to commercial activities, they allow extrapolation based on statistical principles, and they can be aggregated at different levels (Sanchez-Diaz, 2016). The type of models used to quantify freight traffic at the establishment level are referred to as freight trip generation (FTG) models in the literature (Iding et al., 2002; Holguín-Veras et al., 2011). In these models, FTG is calculated as the summation of freight trip attraction (i.e., deliveries received) and production (i.e., shipments sent), with some recent papers including service trips (Holguín-Veras et al., 2018). Jaller et al. (2015) highlights the importance to identify intermediaries that produce freight trips from pure receivers.

There are different variables included as regressors in FTG models, the most common ones being number of employees and area. The type of regressor is important both to increase the accuracy of the models by reproducing the underlying phenomenon, and to allow the application of the model to a different dataset for which only employment information (e.g., census data) or area data (e.g., new developments) may be available. Commercial activity can be used either as a regressor or as a factor to classify establishments into different sectors (Sanchez-Diaz, 2016). The use of commercial activity or industry sectors to classify establishments is crucial because it affects the sample size during the data collection design and the quality of the model (Gonzalez-Feliu and Sánchez-Díaz, 2019; Pani and Sahu, 2019). Some authors have also studied the importance of location, land use, and in general the role of the spatial configuration of establishments in a city (Lawson et al., 2012; Alho and de Abreu e Silva, 2015; Ducret and Gonzalez-Feliu, 2015; Sanchez-Diaz and Gil, 2016; Sánchez-Díaz et al., 2016; Sahu and Pani, 2019). There is a consensus in the literature that location and land use affect FTG and thus should be incorporated in FTG models.

In terms of modeling techniques, the first type of FTG models were based on employment rates or establishments rates (Ogden, 1992; Institute of Transportation Engineers, 2008). Bastida and Holguín-Veras (2009) and Lawson et al. (2012) proposed to use multiple classification analysis to increase the degrees of freedom in the model and improve their statistical fit. Other authors proposed regression models because they allowed to introduce and assess the statistical significance of relevant explanatory variables and provided better alignment with inventory theory (Bartlett and Newton, 1982; Iding et al., 2002; Holguín-Veras et al., 2011). More recent studies identified that non-linear models provided a better alignment with inventory theory and enhanced the prediction power of the models (Sánchez-Díaz et al., 2016; Gonzalez-Feliu and Sánchez-Díaz, 2019). As new FTG patterns were disclosed, new modeling techniques were implemented to address the limitations of standard regression models. Günay et al. (2016) identified that some commercial sectors included several establishments that reported no FTG and that this affected the modeling results, the authors successfully implemented a conditional freight trip generation model to address this challenge. Another challenge associated with the standard regression analyses was the downplay of location in explaining FTG and the risk of biased parameters due to spatial autocorrelation, Sánchez-Díaz et al. (2016) proposed the use of spatial autocorrelation models and location variables to address this challenge. Alho and e Silva (2017) compared different modeling techniques—category analysis, generalized linear models and an ordinal logit model—and found a similar performance in replicating FTG.

Early FTG models often targeted wholesale and manufacturing sectors (Bartlett and Newton, 1982; Ogden, 1992) as well as large terminals such as ports (Al-Deek et al., 2000). Models were then expanded to cover retail given the significant contribution of this sector to urban freight traffic (Holguín-Veras et al., 2012a,b; Holguín-Veras et al., 2014; Alho and e Silva, 2017). As more data was available, it was possible to reflect the differences in logistics between retailers of perishable goods and non-perishable goods in FTG models (Sanchez-Diaz, 2016). The food services sector was later identified as an important contributor to urban freight and FTG models started to include this sector (Holguín-Veras et al., 2012a,b; Oliveira et al., 2017). More recently, establishments in the accommodation sector were identified as a large contributor to local traffic impacts and as a sector with significant interest in sustainable initiatives (Sánchez-Díaz, 2018). However, to the best knowledge of the author, there are no studies in the literature assessing the freight trips generated by offices.

Once FTG models are estimated, they can be applied for different purposes. Application at the establishment level can be useful for logistics facilities design in large manufacturers or ports (Al-Deek et al., 2000; Institute of Transportation Engineers ITE, 2008) At the building level or district level, it can be suitable to identify parking supply needs (Jaller et al., 2013) or other logistics facilities such as consolidation centers (Sanchez-Diaz, 2016). Applications at the zone level or city level can be appropriate for regional and national infrastructure plans and policy making (Bartlett and Newton, 1982). FTG models have a wide range of applications for which implementing the proper aggregation process is key (Holguín-Veras et al., 2011; Pani et al., 2019).

Holguín-Veras et al. (2019) provided an overview of FTG models estimated in different cities and countries and contrasted the results taking into account the overall population, density, GDP, establishments and employees for each city. The results show that FTG per establishment per day range between 1.53 (Oslo, Norway) and 3.55 (Phoenix, United States). FTG per 1000 residents range between 70.4 (Oslo, Norway) and 316.5 (Paris, France). Overall, Paris has the largest FTG with 2 221 769 daily trips, followed by New York City (United States) with 1 924 153, while Oslo has the lowest FTG with 110 463.

3. Method

The data collection and method are applied to a specific case study: The City of Stockholm in Sweden.

3.1. Data collection

This paper studies non-intensive freight sectors (i.e., offices) using data collected in City of Stockholm (Sweden) during the fall of 2016 in collaboration with the traffic office. The geographical area of the study was selected based on the target of the urban freight strategies (e.g., consolidation and off-peak deliveries) formulated in the Stockholm Freight Plan (City of Stockholm, 2015). It covers the central zone of the city which is often congested.

The total number of establishments in the area is 11,279, from which 4,080 are offices. The sample was selected using a random draw from a database containing all the establishments in the area of study. To avoid a predominance of offices (they represent about 35% of the establishments in the area), the random sample was independent from other freight-intensive sectors. As there is no prior information about the mean and standard deviation of FTG for offices, the number of offices sampled was decided as 200 given budget constraints (about 5% of the universe). For the other sectors, the sample size was decided based on the mean FTG and variance from studies previously conducted in Gothenburg, Sweden (Sanchez-Diaz, 2016). The data was segmented in eight different strata using commercial sectors as designated by the Swedish National Industry (SNI) codes (i.e., retail perishable, retail non-perishable, accommodation and food, offices, wholesale, manufacturing). For offices, codes 64–82 which includes financial and insurance activities, real estate and construction activities, professional, scientific and technical activities, and administrative and support service activities. Although healthcare and education can be considered as non-intensive freight sectors they were excluded from this group after piloting the survey and realizing the variety of schemes for ordering and receiving goods, as well as the difficulties in getting responses. Case studies seemed a better alternative than surveys for those two sectors. Fig. 1 shows the geographic distribution of the sample to cover the area of study.

The data collection was implemented in phases, the first phase included internet surveys and mail-in mail-out surveys, the second one included computer-assisted telephone interviews and the third one in-person interviews to ensure a high response rate and that the respondent was the right person to respond to questions. After the data was collected, 50 observations from other sectors were reclassified as office leading to a new sample of 250 observations, from which 118 provided FTG data and 100 provided complete

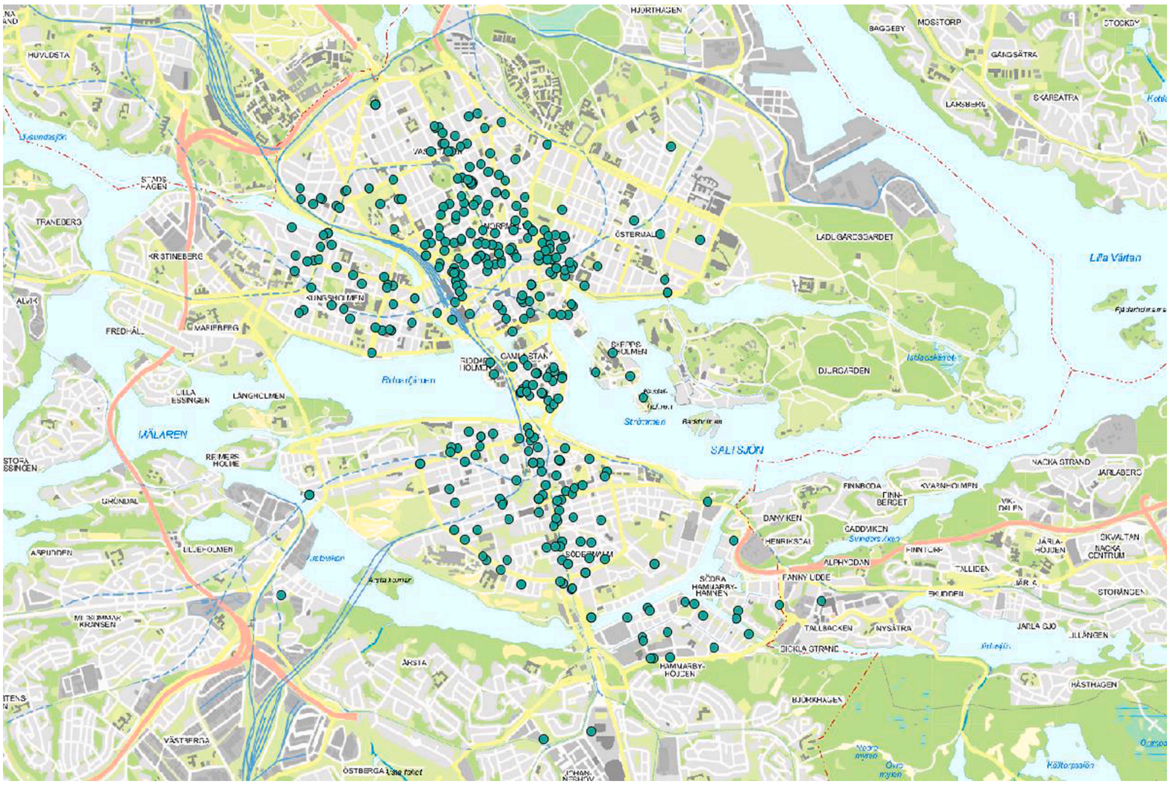

Fig. 1. Geography of the sample.

data to all questions (i.e., 40% out of the sample). The main reasons for not participating in the study were confidentiality, lack of time, or there was no answer (most likely contact information was outdated). The questionnaire implemented was designed in collaboration with freight specialist at the Traffic Office from Stockholm. It was pilot tested with a few establishments before deployment. It included both structured questions to capture data about commercial activity, freight trip generation (i.e., "indicate the number of deliveries and services to the business and from the business for each vehicle type in a typical week"), and what share of these trips performed a service (i.e., defined as "trips that include an activity or service performed by the carrier including cleaning, vending and coffee machine refill, paper refill, etc."). It is noteworthy that regular post mail that is left in mailboxes (e.g., correspondence envelopes) were not considered as freight, but express mail with documents or small office deliveries that require a signature were included. This was reflected in a question illustrating the different types of deliveries.

As one of the objectives of this paper is to assess the contribution of offices to the overall FTG at the city level, it was also necessary to obtain a detailed list of all establishments registered in the area of study. These data were provided by the Swedish Office of Statistics (SCB) and include data about employment, postcode and commercial sector.

3.2. Model development

As discussed in the literature review, FTG models are often estimated using regression analysis. In line with the literature, this paper defines FTG as the summation of freight trip attraction (i.e., deliveries attracted), freight trip production (i.e., shipments produced), combined freight trips (i.e., both a shipment and delivery take place), and service trips (i.e., a service such as replenishment takes place). The common practice is to consider FTG as a continuous variable and estimate regression models that are linear in their parameters. The conversion of deliveries and shipments per day or week to a continuous variable is plausible because establishments in freight-intensive sectors generate both very frequent deliveries as well as deliveries that take place every few weeks which can be merged into a continuous variable.

In the case of offices, where deliveries are less frequent and a lot of them generate very few or no deliveries at all, a modelling technique - such as count data models - that considers zeros and estimates non-negative discrete outcomes may be more appropriate. There are two main types of count data models, Poisson models (used when the mean of the count process is equal to its variance) and Negative Binomial (used when count data is over dispersed) (Washington et al., 2009). In this context, a Negative Binomial seems, a priori, more appropriate given the heterogeneity within offices.

Another challenge that arises when modelling offices FTG is a significant presence of zeros in the responses. These zeros can have two origins, they can be (a) structural zeros meaning that the office does not generate any freight delivery/shipment, or (b) sampling zeros meaning that the frequency is so low that respondents answer zero because they cannot recall the last delivery. As suggested by Washington et al. (2009), in those cases a zero-inflated negative binomial (ZINB) is a suitable model.

Following Washington et al. (2009), the ZINB regression model can be formulated as:

$$\boldsymbol{y_i} = 0 \;\; \boldsymbol{with\;\; probability\;\; p_i} + (1-\boldsymbol{p_i})\left[\frac{\frac{1}{\boldsymbol{\alpha}}}{\frac{1}{\boldsymbol{\alpha}}+\boldsymbol{\lambda_i}}\right]^{1/\boldsymbol{\alpha}} \tag{1}$$

$$y_i = y \;\; with\;\; probability\;\; (1-p_i)\left[\frac{\Gamma\left(\left(\frac{1}{\alpha}\right)+y\right)u_i^{1/\alpha}(1-u_i)^y}{\Gamma\left(\frac{1}{\alpha}\right)y!}\right]^{1/\alpha}, \;\; y = 1, 2, 3\cdots$$

where $Y = (y_1, y_2, \ldots, y_n)$ are independent events, $u_i = (1/\alpha)/[(1/\alpha) + \lambda_i]$. If α is close to zero, then a Poisson model is a better fit. This is tested in the models using a chi-square test to reject the null hypothesis that $\alpha = 0$. The parameters of the model are estimated using Maximum likelihood estimates.

As stated in the second part of the purpose, this paper also seeks to assess what is the contribution of offices to the city's overall FTG. To do so, the author uses a set of linear regression models estimated previously for the other sectors (Sánchez-Díaz, 2018). As all establishments in those sectors generate freight trips there was no need to implement a zero-inflation model, thus the traditional linear regression modeling framework was kept to ease the application of the models at the city-level. Those models use employment as

Table 1
Descriptive statistics for all sectors.

SNI	Obs	Mean FTG/month	Mean Employment	Mean Area (m^2)
Retail non-perishable	63	39.2	4.6	221.1
Retail perishable	65	116.7	6.1	479.0
Accommodation	46	73.5	24.1	3730.2
Food services	43	34.0	6.2	230.7
Wholesale	28	132.3	17.0	483.4
Manufacturing	23	106.5	7.8	818.7
Offices	118	21.3	20.0	661.4

independent variables in ordinary least squares models with robust standard error estimates and each sector is modeled independently. The model parameters are presented in Section 4.

4. Results

4.1. Descriptive statistics

Table 1 shows the descriptive statistics for all industry sectors included in the sample of the original study. Although the focus of this paper is on offices, this table provides context and allows to compare FTG patterns of offices to other freight-intensive sectors. As shown, wholesale, retail of perishable goods and manufacturing have the largest mean FTG rates per establishment, while offices have the lowest mean FTG rate per establishment. In terms of number of employees, accommodation and offices have the highest means, and retailers and food services the lowest ones. The largest area mean corresponds to accommodation, followed by manufacturing and offices. In essence, offices have high employment per square meter and low FTG per establishment.

Fig. 2 and Table 2 present a histogram for offices monthly FTG and the descriptive statistics for different variables. Fig. 2 confirms the hypothesis of over dispersion that calls for a Negative Binomial instead of a Poisson model.

As shown in the Table 2 and Fig. 2, the mean of FTG is 21.3 trips per week with a relatively high dispersion (CV = 162%). The range of FTG is wide with almost 30 offices reporting no FTG and six offices generating more than 100 freight trips per month (most of them related to media and advertisement). It is noteworthy that among the offices that reported having no deliveries or shipments at all, some of them explained that their type of business does not need any office supplies, while others explained that they rarely have something delivered. The share of intermediaries (i.e., offices both receiving deliveries and sending shipments) is 50% which is lower than what was found for freight-intensive sectors. The mean of number of service trips is 1.9, which represents about 9% of freight trips. The mean number of employees is 20, with a maximum of 320 employees reported. The mean area is 661 m2, but this is misleading as one of the respondents reported having 30,000 m2, without this respondent the mean would be 365 m2.

Respondents also answered about the attributes of the delivery, vehicles used for the deliveries and where the deliveries take place. The most common products delivered where paper supplies and food (fruits and coffee were common answers), and recycled paper was often mentioned as shipped product. In terms of weight, 63% of respondents received less than 40 kg per month, 19% between 40 kg and 200 kg, 17% between 200 kg and 2000 kg, and only 1% more than 2000 kg. In terms of vehicles, cars were used for 18% of the trips, light vehicles like vans and pick-ups for 42% of the trips, medium duty trucks were used by 10%-it is worthy of mention that certain parcel distributors use medium duty vehicles in Sweden— and other vehicles, such as, cargo bikes and electric small vehicles 30% of the trips. Most deliveries were delivered through the main entrance (82%), while 11% were delivered through the loading zones, and 7% through a different way. The most common type of delivery were packages (45%) and documents (33%), as expected only 2,6% were pallets or roller cages. This is the opposite to freight-intensive sectors where pallets and roller cages account for 50% of deliveries.

A more detailed look into the data allows to identify some sub-sectors that have different FTG patterns. The means for FTG, number of employees and area for these sub-sectors are presented in Table 3. As shown, offices in the advertisement sub-sector have the largest FTG, followed by offices in construction and real estate, finances, and HR. Finances offices have the largest mean for number of employees and area. Some sub-sectors do not have enough observations to be analyzed separately and were classified together as others.

4.2. Offices FTG modelling results

As discussed in Section 3, count data models were selected to replicate Offices FTG. As shown in the analysis of the data, (i) the FTG data is over dispersed as revealed by the large CV, and (ii) there are two classes of offices that answered that they had no FTG: (a) the

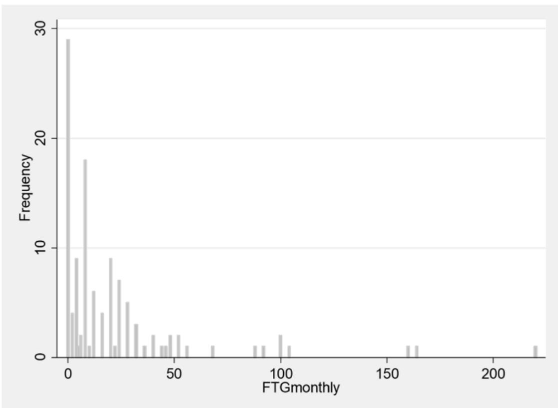

Fig. 2. Dispersion of FTG for offices.

Table 2
Descriptive statistics for offices.

SNI: Offices						
Variable	Unit	Obs.	Mean	CV	Min	Max
FTG	trips/month	118	21.3	162%	0	220.0
FTA	deliveries/month	118	11.9	138%	0	82.0
Intermediary	1 if yes, 0 if not	118	0.5	n.a.	0	1.0
Interm. FTP	trips/month	59	19.2	175%	0	35.5
Service trips	service/month	100	1.9	308%	0	41.6
FG	interval freight	106	1.7	n.a.	1	5.0
Employment	employees	109	20.0	219%	1.0	320.0
Area	m2	100	661.4	446%	3.0	30,000.0

Table 3
Descriptive statistics for offices sub-sectors.

SNI	Obs	Mean FTG/month	Mean Employment	Mean Area (m^2)
Advertisement	14	46.3	26.0	500.5
Construction & real estate	11	41.3	14.8	265.9
Finances	21	23.4	31.5	739.2
HR	5	17.6	19.0	340.7
Others	67	12.4	16.0	747.8

ones for which the nature of the business does not require any delivery, and (b) those for which the frequency of deliveries is very low. Thus, a Zero-Inflated Negative Binomial (ZINB) was proposed for the model. As a low correlation was found between area and number of employees for offices (corr = 0.13), a model including the two terms is proposed. Huber variance estimators were used in the ZINB model to increase its robustness against heteroskedasticity (Freedman, 2006).

Three models were estimated to allow the application to cases where only (1) number of employees is available, (2) area is available, and (3) case where both employment and area are available. Each model has a count model (top of Table 4) and an inflation model (bottom of Table 4). The parameters of the count model are presented as incidence rate ratios, i.e., the estimated rate ratio for a unit increase in the variable given other variables are held constant. The zero-inflated part of the model estimates the likelihood of being a structural zero (i.e., the office does not need any deliveries or shipments) using a logit model. The parameters displayed for the zero-inflate model were exponentiated for ease of interpretation. Only variables that were significant at least at the 10% level were included in the model. A chi-square test was performed on the parameter alpha and confirmed that data are over dispersed and that negative binomial models should be preferred over Poisson models (i.e., The null hypothesis *Ho: alpha = 0* was rejected at the 95% level of confidence).

As shown in the inflation models, the baseline odds of being among those that never generate freight trips is 1.48 for ZINB-1, 1.95 for ZINB-2 and 1.51 for ZINB-3. The three models capture the extremely low odds of being a structural zero for offices in the construction and real estate sub-sector compared to other sub-sectors. For ZINB-1, the odds of no FTG are decreased by 0.80 per additional employee. For ZINB-2 and ZINB-3, the odds of no FTG are decreased by 0.90 per additional 10 m2 of area. In essence, larger offices are less likely to never generate freight trips; and if it belongs to the construction and real estate sector it is very unlikely that it never generates freight trips.

Table 4
Zero inflated negative binomial models for offices.

Variables	ZINB 1 (employees)	ZINB 2 (area)	ZINB 3 (area & employees)
Intercept	21.255***	15.996***	14.005***
Advertisement offices	2.793***	3.592***	4.367***
Construction & real estate offices	–	2.570*	2.761*
Number of employees	1.004*	–	1.007***
Employees * Advertisement offices	0.992***	–	–
Area (10 m^2) * Finance offices	–	1.004***	–
Logit (inflation model)			
Intercept	1.48	1.95	1.51
construction and real estate offices	2.3E-9***	4.6E-9***	2.5E-8***
Number of employees	0.80***	–	–
Business area (10 m^2)	–	0.904***	0.904***
Number of observations	118	106	106
/lnalpha	−0.061	−0.378	−0.392
alpha	0.94	0.71	0.68
Log pseudolikelihood	−428.24	−370.76	−369.7

Note: Variables significant at 1% are marked as ***, 5% marked as **, 10% marked as *.

For the count models, three sub-sectors have a significant different FTG: advertisement, construction & real estate, and finances. The results for ZINB-1 show an overall baseline of 21 monthly freight trips, if the office belongs to the advertisement sub-sector it generates 2.8 times more. Also, each additional employee increases FTG by 1.004 times for most offices except for advertisement offices for which the effect of employment is negligible.

For ZINB-2, the baseline is 16 monthly freight trips. If the office belongs to advertisement it generates 3.6 times more trips than the baseline, if it belongs to construction and real estate sub-sector it generates 2.6 more trips. An increase in area only affects FTG for finance offices where an increase of 10 m2 increases FTG 1.004 times.

For ZINB-3, the baseline is 14 monthly freight trips and each additional employee increases FTG times 1.007. For advertisement offices FTG is 4.4 times higher, and for construction and real estate offices FTG is 2.8 times higher.

Fig. 3 shows the model fit, each dot represents a response for an office. The y-axis shows FTG reported for that office in the survey and the x-axis shows the model estimate, the dotted line represents what would be a perfect prediction. As shown, the models have a fair prediction power but there are some challenges predicting large values of FTG. A drilldown into the data shows that some offices have very specific activities (e.g., banking) for which even a small number of employees can generate many freight trips, these specific cases are not captured in the model.

4.3. Freight-intensive sectors FTG modelling results

As this paper seeks to assess the overall share of offices FTG at the city-level, it is necessary to estimate FTG for other sectors as well. As explained in Section 3, these models were estimated using ordinary least squares with robust estimators. The results are shown in Table 5.

As shown, most models have an intercept and a coefficient for the number of employees, except retail of perishable goods where the intercept was not found significant and thus FTG is assumed to be better expressed by an employee rate. The largest baseline is found for wholesale (97.2 monthly freight trips), followed by manufacturing (58.9) and accommodation (45.9). However, the largest effect of number of employees is found for retail of perishable goods (18.2), followed by manufacturing (6.1) and wholesale (2.1). Although the modelling technique used for these models is different than the one used for offices, it is possible to see that the baseline number of deliveries for offices is very low compared to freight-intensive sectors.

4.4. Application to the city level: FTG contribution by sector

The models described in Table 4 allow to quantify the FTG for different types of offices, while the ones presented in Table 5 allow to quantify the FTG of other sectors. As explained before, an advantage of these models is the use of number of employees and commercial activity as the main factors to estimate FTG. This allows the use of economic data collected by the Office of Central Statistics (SCB) to

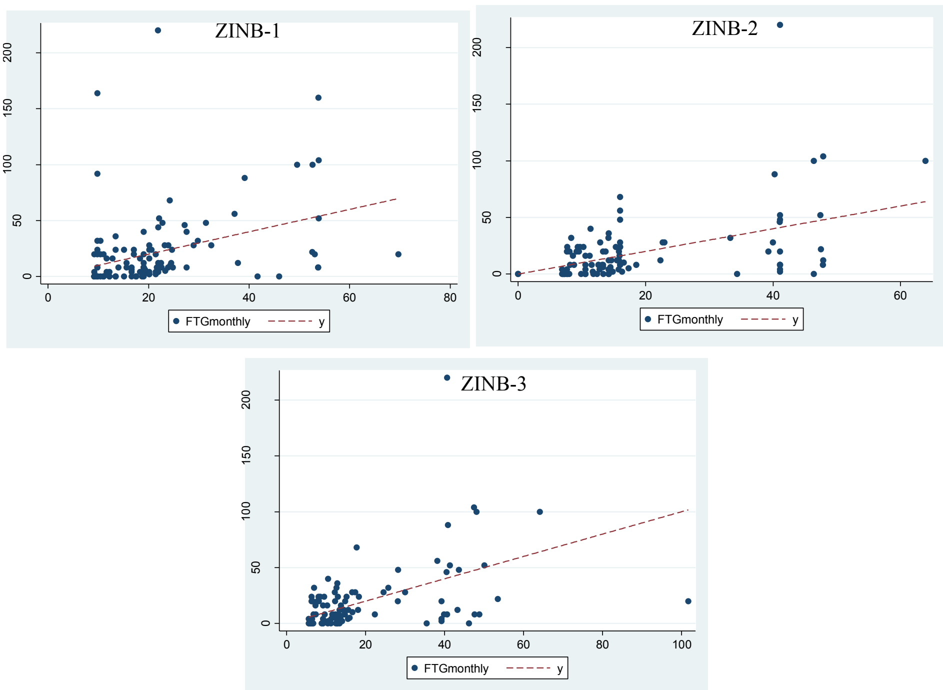

Fig. 3. Scatter plot FTG predicted vs. reported in responses.

Table 5
Linear models for freight-intensive sectors.

Comercial sector	Employment models			
	Observations	Intercept	Emp.	R2
Retail perishable	65	–	18.16 *(5.23)*	0.75
Food services	43	27.80 *(5.22)*	1.00 *(1.84)*	0.06
Retail non-perishable	63	31.52 *(6.06)*	1.66 *(1.82)*	0.06
Accommodation	46	45.92 *(4.80)*	1.14 *(2.56)*	0.22
Manufacturing	23	58.92 *(2.30)*	*6.12* *(2.78)*	0.34
Wholesale	29	97.24 *(3.18)*	2.08 *(5.61)*	0.22

Notes: Monthly FTG is the dependent variable. t-stat are displayed between parenthesis under each parameter. Only variables significant at the 10% level of confidence are retained.

estimate the FTG for each office and establishment in the area of study (every business activity must register in this database for tax purposes). This entails some challenges: (i) the headquarters problem, i.e., employment data is reported for location from where employees get their paycheck, but they do not necessarily work there (Stone et al., 2008), and (ii) the risk for outdated information. However, it is possible to use this dataset to obtain FTG estimates for the entire city after some data cleansing. Table 6 presents the estimates for the municipality of Stockholm.

As shown in the table, the total number of freight trips generated daily by establishments in the municipality of Stockholm—where the population is about 900 000—is 28,423, meaning 31.6 freight trips per 1000 residents. This figure is about half of the one reported for Oslo and ten times lower than the one reported for Paris by Holguín-Veras et al. (2019). This can be explained partly by the selection of the study zone and by the selection of the industry sectors studied in the different studies. For Stockholm, the focus was on the area of the city within the congestion charge which is characterized by a predominance of retailers, food services and small wholesalers. The construction sector was not included (although some stores selling construction materials are classified as wholesale or retail non-perishable), and transportation and warehousing which take place in the suburbs of the city and are characterized by a large freight trip production were not included either.

It is noteworthy that these models only estimate FTG which does not translate directly into freight vehicles entering the area, as one single vehicle can fulfil several deliveries/ shipments calls in a day and the number of stops per vehicle varies across sectors. From the almost 30,000 daily freight trips generated in Stockholm, 85% come from freight-intensive sectors and 15% from offices. The reason for the significant contribution of offices to the overall FTG is the number of offices (36% of all establishments) and the amount of people they employ (62% of all employees) compared to freight intensive sectors. Fig. 4 shows the geographical distribution of all freight trips.

Fig. 4 shows the geographical distribution of FTG. As shown, freight-intensive sectors contribute the most to FTG in most zones, except around Central Station (center of the area) and some areas in the periphery of the municipality, where offices contribute a significant share of FTG.

5. Policy implications

The results presented in the previous sections have interesting implications for different urban freight stakeholders. For municipal authorities, these FTG models provide a tool to assess freight traffic in urban areas with a large number of offices, which as shown in Fig. 4 correspond to the inner city center where congestion and pollution have the largest impact. Measuring the amount of freight traffic generated in these areas can lead to better infrastructure planning, better management of urban space (e.g., loading zones

Table 6
Estimation of daily FTG by commercial sector in the City of Stockholm (municipality).

Commercial sector	Establishments		Employees		FTG	
	Number	Share	Number	Share	Number	Share
Accommodation	182	2%	6,866	3%	680	2%
Manufacturing	562	5%	3,563	2%	2,288	8%
Food services	2,082	18%	24,392	12%	3,428	12%
Retail non-perishable	2,061	18%	17,627	8%	3,941	14%
Retail perishable	542	5%	6,577	3%	4,977	18%
Wholesale	1,770	16%	19,414	9%	8,854	31%
Overall Freight-intensive	7,199	64%	78,438	38%	24,168	85%
Offices	4,080	36%	1,29,130	62%	4,255	15%
Grand Total	11,279	100%	2,07,568	100%	28,423	100%

Fig. 4. Monthly FTG per postcode in area of study (Stockholm, Sweden): Offices vs Freight-intensive sectors. Note: White dots represents the magnitude of FTG from offices.

management), and more informed urban freight policy decisions. At the national level, this information can also support the enactment of regulations and guidelines to include logistics facilities for large buildings that host an important number of offices.

In terms of urban freight policy, although most efforts are oriented towards freight-intensive sectors there are some research and practical applications of consolidation programs in buildings hosting numerous offices (Holguín-Veras and Sánchez-Díaz, 2016). The Delivery Service Plans (DSP) pioneered by Transport for London (2013) showed that it was possible to encourage offices to quantify their deliveries and suggest plans to decrease the number of deliveries using a consolidation rationale. Transport for London (2013) reports that these plans can lead to decreases between 20% and 40% in the number of deliveries received.

The City of Stockholm also considered a consolidation strategy as part of their Freight Plan (City of Stockholm, 2015). Implementing a consolidation strategy targeting offices as the one described in (Transport for London, 2013) may require some innovative engagement strategies as most offices in this study declared to be satisfied with the regular deliveries (53% have a positive perception), and are not interested on consolidation (63% had a negative perception). Some ways to foster consolidation could be to introduce them as requirements for permits renewal as was done with DSP in London, or use organizations that can influence businesses, such as, Business Improvement Districts (Brettmo and Browne, 2020).

Offices FTG information is also valuable for architects and real estate developers who lack information to plan suitable logistics facilities in their buildings. These models can provide a good insight at an early stage of planning, leading to designs that facilitates access for freight vehicles. This can bring benefits for office districts, such as, decreasing congestion impacts and pollution, which in turn will make their commercial space more attractive. Having models that can estimate offices FTG using area and sub-sectors as predictors becomes very helpful in early planning when there is limited information on the number of employees that will work in the premises.

6. Conclusions

This paper aims at filling the existing gap in the literature about freight traffic impacts of non-freight intensive sectors (i.e., offices). The data analysis and the statistical modeling proposed allowed to characterize FTG patterns of offices and to assess their overall contribution to the city's FTG. In terms of the method, it was found that offices FTG tends to be over dispersed and that null FTG can have two different explanations (i.e., either the office does not require any delivery or deliveries are very sporadic), thus a zero-inflated negative binomial was suggested as the most appropriate model.

In terms of the data analysis, the results show that a typical office generates few freight trips compared to other freight-intensive sectors, on average 21 vs. 79 freight trips per month. The data analysis also showed some heterogeneity within offices: offices in the advertisement business generate on average 46 freight trips per month, while offices in human resources generate 18. As expected, offices with more employees have a larger FTG, but the effect is small. Area can be used as a factor to predict FTG if employment is not available. Moreover, the models show that area is a better predictor for the zero-inflated part of the model that identifies zero FTG offices from FTG offices with low FTG. The models also show that offices doing construction and real estate businesses are more likely to generate freight trips.

The analysis of the data for the entire municipality of Stockholm and the application of the models show that offices represent 36%

of the establishments, 62% of employees and 15% of FTG. Offices FTG tend to be located in the city center near the central station and near the shopping districts, which is where more strategies to mitigate traffic congestion are required.

Along with the contributions of this research, there are also some limitations. Two main limitations have been identified, the first one is that—as is the case with all survey based FTG models—the data comes from stated information and the numbers cannot be verified. Some efforts were done to mitigate the error: (i) when conducting the survey the interviewer tried to contact the right person even though that entailed multiple calls or visits, and (ii) during the data processing stage when some abnormal entry was found respondents were contacted a second time to double check their responses. The second limitation is related to the number of observations. As the number of offices in the city is large (4,008 in the area of study), it is challenging to include in the sample a significant share of the universe. Moreover, collecting FTG data from offices required more time than for freight-intensive sectors, and thus was more expensive, because of the time it took to find the right person to answer the questionnaire. It is expected that the insights gained from this study in terms of variance in the FTG data can help to design an optimal sample in future studies.

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